# Ecohab: Hyperspectral Optical Properties of Red-Tide Blooms

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## LONG-TERM GOALS

The goal of our project is the bio-optical characterization of dinoflagellate and other red-tide blooms, to facilitate the optical detection and monitoring of these blooms from above the sea surface.

## OBJECTIVES

We want to explain the origin of the red surface color of dense dinoflagellate blooms, and the difference to other dense phytoplankton blooms that do not show this characteristic color, e.g. diatoms (brown tides) or chlorophytes. Our working hypotheses assumes that the red color of dinoflagellate blooms originate from *in vivo* fluorescence of chl *a*, but we are also considering the hypothesis that the back scattering properties of dinoflagellate cells or other bloom associated particles might change the backscattering properties and hence the upwelling radiance. The interpretation of the surface color will be based on a comparison of measured upwelling radiance and numerical simulation (Hydrolight v.4.1). The input to the simulation will based on measured depth profiles of optically relevant variables.

## APPROACH

Given the strong light absorption of water in the red, the depth of origin of the surface color is close to the surface (Maske, et al., 1998). We are measuring the fine scale (0.2 m) near surface distribution of red-tide forming organisms, and want to compare them to the apparent and inherent optical properties near the surface. To obtain near surface profiles we build an electrically triggered sampler that is taking 12 samples (4 x 1.8 liter and 8 x 300 ml) simultaneously between 0 and 2.2 m (dz = 0.2m). The sampler is floated away from the ship into a high density, undisturbed red-tide patch before triggering. The water samples are being processed for pigment concentration (HPLC), particulate absorption spectra

# Report Documentation Page

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14. ABSTRACT
**The goal of our project is the bio-optical characterization of dinoflagellate and other red-tide blooms, to facilitate the optical detection and monitoring of these blooms from above the sea surface.**

15. SUBJECT TERMS

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and particle counts. The vertical profiles of spectral downwelling irradiance and upwelling radiance will also be modeled with high vertical resolution, using the Hydrolight (v 4.1) radiative transfer model with measured profiles of inherent optical properties. Some unknown parameters that have to estimated and adjusted to fit the measured radiometric data are the quantum efficiency of the fluorescence of Chl a, the volume scattering function of empty dinoflagellate thecae, and other particles (dinoflagellates, bacteria, virus).

From comparisons of modeled and measured irradiance and radiance profiles and reflectance, we expect to gain information on the dominant source of the red-tide surface color. The origin of red upwelling radiance perceived by the eye should be obvious from the spectral shape of the upwelling radiance. On the other hand, fluorescence emission would give us a well-defined spectrum with a maximum at 685nm or longer, and the enhanced elastic backscatter produced by the particles would give a wider peak.

## WORK COMPLETED

A high Lingulodinium polyedrum bloom was measured off La Jolla/San Diego Jolla, 26 + 27. Sept. 2001 on two days. We concentrated on near surface water sampling and radiometry evaluating 3 profiles.

The 0-220 cm Linear Array Vertical Surface Sampler (LAVSS) with up to 12 sampler positions and electrical remote release was improved and used in our recent red tide sampling off San Diego. The remote release mechanism allows us to sample undisturbed surface layers away from the research platform. The sampler is more reliable now and some 350ml samplers were substituted by 1.8 liter samplers. WETLabs upgraded our HISTAR *in situ* spectrophotometer, which measures hyperspectral absorption and beam transmission. The instrument was used for near surface profiling but its performance has not yet been tested in the laboratory after the reconfiguration. The Hydrorad-2 was used to measure hyperspectral radiance and irradiance both above and below water. These data will be used to measure in situ and remote sensing reflectance for comparison with Hydrolight modeling results. The Hydrolight (v 4.1) model was installed and is being used to simulate measured conditions in the Montererey Bay (2000) and La Jolla (2001) blooms, and in hypothetical sensitivity studies. Some modeling results from Monterey Bay were presented at Ocean Optics XV (Maske et al. 2000).

## RESULTS

The red-tide bloom observed off San Diego showed the expected very high chlorophyll a concentrations (~100mg Chl a $m^{-3}$). About 60 percent of the homogenously pigmented Lingulodinium cells had shed their thecae, the suspended thecae were still suspended in the water samples, increasing the particle concentration 60 percent. We found surprisingly high bacteria concentrations (~$10^{11}$ cell $m^{-3}$). A preliminary sample also indicated very high virus concentration. We don't know yet if the numbers are sufficiently high to significantly affect the optical properties. In this year's samples we observed a well mixed layer of extremely high pigments and particle concentration in the top 2.2 meters, with none of the fine structure suggested by the data from Monterey Bay in August 2000. The difference could have been due to the different species composition, the lower pigment concentration or the hydrographic conditions in Monterey Bay. We expect to complete to analysis of these data soon, and will include them both in our final report and in a manuscript to be submitted for publication.

| PARAMETER | METHOD | COMMENTS |
|---|---|---|
| Phytoplankton cell concentration | Transmission microscopy | |
| Phytoplankton cell size | Transmission light and epifluorescence microscopy | |
| Empty Dinoflagellate thecae concentration | Transmission light microscopy | |
| Bacteria cell concentration | DAPI | |
| Virus cell concentration | Sybr-Green | |
| Absorption coefficient of particles, ap | Filter pad, spectrophotometry | 50% duplicate samples |
| ap-depigmented | Filter pad | 50% duplicate samples |
| a-total | HiStar in situ | |
| c-total | HiStar in situ | |
| HPLC pigments | Wright et al., 1991 | 50% duplicate samples |
| Fluorometric Chl a concentration | Trees et al., 2000 | |
| $E_s$ (7 wavelength, continuous) | Satlantic | 410, 440, 489, 511, 553, 668, 684 nm |
| Lu(z, $\lambda$) and Ed(z, $\lambda$) | Hydrorad | d$\lambda$ = 0.5nm, |
| Lu-air($\lambda$) | HydroRad | |

## IMPACT/APPLICATIONS

Our characterization of the near-surface hyperspectral inherent and apparent optical properties associated with red-tide blooms will provide a basis for assessing the feasibility of using hyperspectral remote sensing methods to identify the occurrence and distribution of specific red-tide organisms.

## TRANSITIONS

None during this grant period.

## RELATED PROJECTS

None.

***Figure 1. Vertical array surface sampler (VASS) pictured under water. 12 individual sample bottles (0-2.2m, $\Delta$z=0.2m) are simultaneously triggered electrically.***

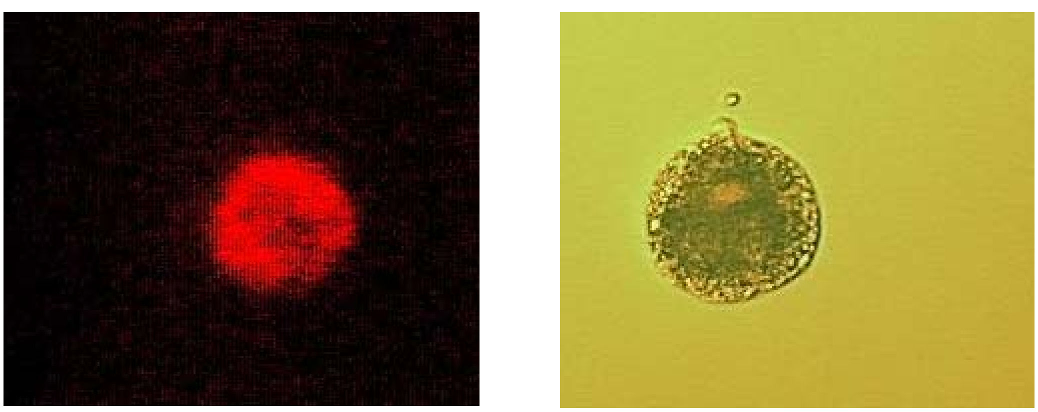

***Figure 2. Lingulodinium polyedrum cell without theca (about 60% of total cells) from the July bloom off San Diego, comparing light transmission and autofluorescence images (images 240 x 200μm). Note the spherical shape without strong cell wall, this cell shape might represent a type of cycte.***

***Figure 3. Empty thecae of Lingulodinium polyedrum from the July bloom off San Diego (images 150 x 140µm). The number of empty thecae found corresponds to about 60% of live cells, thus is about the number of cells found without thecae.***

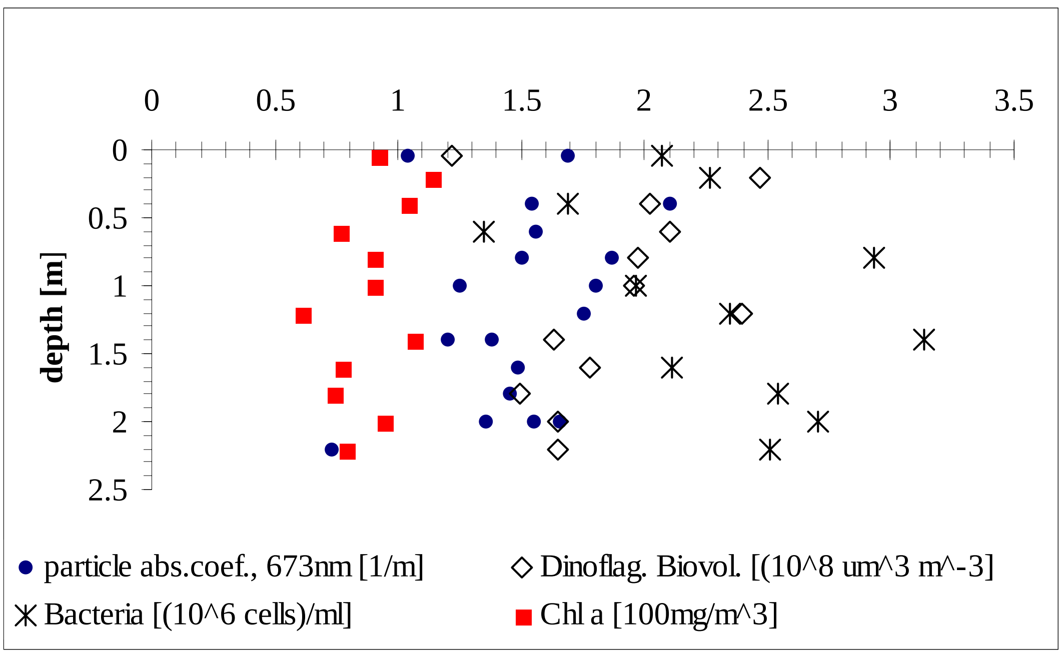


***Figure 4. One example of a near surface profile of optically relevant biological variables, July 26, 2001 Lingulodinium polyedrum bloom off San Diego.***